Run-11 RHIC Polarimetry Analysis

version 0.1

I. Alekseev, E. Aschenauer, G. Atoyan, A. Bazilevsky, A. Dion, H. Huang,
Y. Makdisi, A. Poblaguev, W. Schmidke, D. Smirnov, D. Svirida, and A. Zelenski

September 8, 2011

Abstract

We present results on the measurement of polarization of proton beams in RHIC run 11.

Contents

1 Results

In 2011 run every attempt was made to collect good data with all RHIC polarimeters in every fill. As the result of this effort, in most of the 2011 fills we have a few measurements of the beam polarization obtained with the p-Carbon polarimeters, $P^{(\mathrm{p})}_{\mathrm{crb}}$ (p = B1U, Y1D, B2D, Y2U; p = U, D; or p = B, Y), corresponding horizontal and vertical beam profiles, $R^{(\mathrm{p})}_v$ and $R^{(\mathrm{p})}_h$, and the average fill polarization, P_{jet}, from the H-jet polarimeter. Using available measurements we calculate the average polarization[1] $\langle P^{(\mathrm{p})}\rangle$ with its associated statistical error $\Delta\langle P^{(\mathrm{p})}\rangle$, and polarization profiles $\langle R^{(\mathrm{p})}_v\rangle$ and $\langle R^{(\mathrm{p})}_h\rangle$ for each p-Carbon polarimeter.

While polarization P_{jet} is measured directly, the polarization $P^{(\mathrm{p})}_{\mathrm{crb}}$ is initially calculated using the predictions for the p-Carbon analyzing power which in turn based on the 2004 run data [**??**]. According to our strategy we scale the fill average p-Carbon numbers to the H-jet value:

$$\langle P^{(\mathrm{p})}\rangle \equiv \langle P^{(\mathrm{p})}_{\mathrm{crb}}\rangle' = \langle P^{(\mathrm{p})}_{\mathrm{crb}}\rangle \times k_{\mathrm{jet/crb}}, \tag{1}$$

where the normalization factor $k_{\mathrm{jet/crb}}$ is defined by the ratio of the averages over all (or selected) fills:

$$k_{\mathrm{jet/crb}} = \frac{\left\langle P_{\mathrm{jet}}\right\rangle_{\mathrm{fills}}}{\left\langle \langle P^{(\mathrm{p})}_{\mathrm{crb}}\rangle\right\rangle_{\mathrm{fills}}} \tag{2}$$

1.1 Beam polarization in a fill

In general, we do not see a reason for using measurements from either upstream or downstream polarimeter alone. Therefore, we calculate the final fill polarization, $\langle P\rangle$, for each beam by calculating the weighted average of the two p-Carbon polarimeters in the ring:

$$\langle P\rangle = \frac{\sum\limits_{\mathrm{p=U,D}} \langle P^{(\mathrm{p})}\rangle \left(1/\Delta\langle P^{(\mathrm{p})}\rangle\right)^2}{\sum\limits_{\mathrm{p=U,D}} \left(1/\Delta\langle P^{(\mathrm{p})}\rangle\right)^2}, \qquad \underset{\mathrm{stat}}{\Delta}\langle P\rangle = \frac{1}{\sqrt{\sum\limits_{\mathrm{p=U,D}} \left(1/\Delta\langle P^{(\mathrm{p})}\rangle\right)^2}} \tag{3}$$

The above equation defines the average beam polarization in a fill. However, the physicists analyzing data from the collider experiments STAR and PHENIX are interested in the beam polarization in collisions. This polarization takes into account the intensity profile of the both beams:

$$\langle P\rangle_{\mathrm{coll}} = \frac{\iint \langle P\rangle(x,y) I^{(\mathrm{B})}(x,y) I^{(\mathrm{Y})}(x,y)\,dxdy}{\iint I^{(\mathrm{B})}(x,y) I^{(\mathrm{Y})}(x,y)\,dxdy} \tag{4}$$

Assuming gaussian polarization and intensity profiles the relation between $\langle P\rangle$ and $\langle P\rangle_{\mathrm{coll}}$ is:

$$\langle P\rangle_{\mathrm{coll}} = \langle P\rangle \times k_{\mathrm{coll}} \qquad \text{where} \qquad k_{\mathrm{coll}} = \frac{\sqrt{1+\langle R_h\rangle}\sqrt{1+\langle R_v\rangle}}{\sqrt{1+\frac{1}{2}\langle R_h\rangle}\sqrt{1+\frac{1}{2}\langle R_v\rangle}} \tag{5}$$

The total uncertainties on the average beam polarizations, $\Delta\langle P\rangle$ and $\Delta\langle P\rangle_{\mathrm{coll}}$, as defined above, include both statistical and systematic components,

$$\Delta\langle P\rangle = \underset{\mathrm{stat}}{\Delta}\langle P\rangle \oplus \underset{\mathrm{syst}}{\Delta}\langle P\rangle.$$

In the following we discuss them in details.

[1] The better way is to calculate a luminosity weighted average.

1.2 Uncertainties on beam polarization

Normalization to H-jet It is clear that due to normalization to the H-jet the final fill polarization directly depends on the resolution of the H-jet measurement itself. To estimate this error, Δ^{norm}, we use the statistical error $\Delta k_{\mathrm{jet/crb}}$ on the normalization factor $k_{\mathrm{jet/crb}}$. Note that for a single fill Δ^{norm} is simply equal to the statistical error on the H-jet measurement, while it decreases as $\frac{1}{\sqrt{N}}$ when the number (N) of combined fills increases.
We regard this error as uncorrelated between the yellow and blue beams.

H-jet molecular background The average polarization values P_{jet} rely on the hydrogen jet target polarization as measured by a Breit-Rabi polarimeter. The jet target is believed to be contaminated with molecular hydrogen whose polarization is unknown (???). A special study was performed to estimate the error on the P_{jet} in 200X [**??**]. In the current analysis we use the value of $\Delta^{\mathrm{mol}}_{\mathrm{jet}} = 2\%$ obtained for 250 GeV beams.
We regard this error as correlated between the yellow and blue beams.

Other H-jet background The error $\Delta^{\mathrm{bkg}}_{\mathrm{jet}}$ represents the uncertainty due to other backgrounds contributing to the measurement of P_{jet}. As the H-jet measures polarization of the two beams simultaneously, it is believed that the main cotribution comes from the interference between the two beams. We did not estimate this unceratainty in 2011, instead we use the value of 3% as was defined in the previous runs.
We regard this error as correlated between the yellow and blue beams.

Upstream vs downstream polarimeter In the fills where measurements from the two polarimeters in the same ring are available we observe non-statistical variations in the measurements even when they closely follow each other in time. At the moment, the observed fluctuations cannot be associated with a single source or a known difference in the devices therefore, we assign a systematic error, $\Delta^{\mathrm{U\ vs\ D}}$, on the fill average. We estimate the systematic uncertainty of this kind by calculating the difference between the fill average as measured by the two polarimeters. From Figure **??** the average difference is XXX. In order to cover most of our measurements we conservatively assign $\Delta^{\mathrm{U\ vs\ D}} = XXX$.
We regard this error as uncorrelated between the yellow and blue beams.

Polarization profile We define error Δ^{R} as an error on the average fill polarization in collisions $\langle P \rangle_{\mathrm{coll}}$. This is not a systematic error but rather a propagation of the statistical errors on the measured quantities $\langle R_h \rangle$ and $\langle R_v \rangle$ according to equations (5). As one can see on Figure **??** the statistical errors on $\langle R_h \rangle$ and $\langle R_v \rangle$ are quite large and systematic effects are not clearly visible as they must be on the same or smaller level as statistical fluctuations. For now we use the statistical error as the total uncertainty on $\langle R_h \rangle$ and $\langle R_v \rangle$ leaving the estimation of the systematic effects for the future analysis. We regard this error as uncorrelated between the yellow and blue beams.

Summary For the sources of systematic uncertainties discussed above the total errors on the average fill polarization can be written as:

$$\Delta \langle P \rangle = \underset{\mathrm{stat}}{\Delta} \langle P \rangle \oplus \langle P \rangle \times \Delta^{\mathrm{U\ vs\ D}} \tag{6}$$

$$\Delta\langle P\rangle_{\text{coll}} = \underset{\text{stat}}{\Delta}\langle P\rangle_{\text{coll}} \oplus \langle P\rangle_{\text{coll}} \times \left(\Delta^{\text{U vs D}} \oplus \Delta^{\text{R}}\right) \tag{7}$$

and for the average over a subset of selected fills we have:

$$\Delta\Big\langle\langle P\rangle\Big\rangle_{\text{fills}} = \Big\langle\Delta\langle P\rangle\Big\rangle_{\text{fills}} \oplus \Big\langle\langle P\rangle\Big\rangle_{\text{fills}} \times \left(\Delta^{\text{norm}} \oplus \Delta^{\text{mol}}_{\text{jet}} \oplus \Delta^{\text{bkg}}_{\text{jet}}\right) \tag{8}$$

$$\Delta\Big\langle\langle P\rangle_{\text{coll}}\Big\rangle_{\text{fills}} = \Big\langle\Delta\langle P\rangle_{\text{coll}}\Big\rangle_{\text{fills}} \oplus \Big\langle\langle P\rangle_{\text{coll}}\Big\rangle_{\text{fills}} \times \left(\Delta^{\text{norm}} \oplus \Delta^{\text{mol}}_{\text{jet}} \oplus \Delta^{\text{bkg}}_{\text{jet}}\right) \tag{9}$$

1.3 Uncertainty on single spin asymmetry

For measurements of the single spin asymmetry the experiments use the average of the two beam polarizations $\frac{\langle P^{(\text{B})}\rangle + \langle P^{(\text{Y})}\rangle}{2}$. The total uncertainty is then calculated using the values in Table**??** for different beams. Taking into account the proper correlation between the two beams we obtain:

$$\Delta = \frac{1}{2} \times (\Delta^{\text{norm}})^{(\text{B})} \oplus (\Delta^{\text{norm}})^{(\text{Y})} \oplus \left((\Delta^{\text{mol}}_{\text{jet}})^{(\text{B})} + (\Delta^{\text{mol}}_{\text{jet}})^{(\text{Y})}\right) \oplus \left((\Delta^{\text{bkg}}_{\text{jet}})^{(\text{B})} + (\Delta^{\text{bkg}}_{\text{jet}})^{(\text{Y})}\right) \tag{10}$$

1.4 Uncertainty on double spin asymmetry

Similarly, the double spin asymmetry measurements use the product of two beam polarization $\langle P^{(\text{B})}\rangle \times \langle P^{(\text{Y})}\rangle$. The total unceratainty in this case is:

$$\Delta = (\Delta^{\text{norm}})^{(\text{B})} \oplus (\Delta^{\text{norm}})^{(\text{Y})} \oplus \left((\Delta^{\text{mol}}_{\text{jet}})^{(\text{B})} + (\Delta^{\text{mol}}_{\text{jet}})^{(\text{Y})}\right) \oplus \left((\Delta^{\text{bkg}}_{\text{jet}})^{(\text{B})} + (\Delta^{\text{bkg}}_{\text{jet}})^{(\text{Y})}\right) \tag{11}$$